ENERGY CONVERSION APPARATUS

BACKGROUND OF THE INVENTION

1. Field of Invention

This invention relates to energy conversion apparatus and more particularly to electrical energy conversion apparatus designed to operate in conjunction with batteries.

2. Description of Related Art

Many vehicles employ lead-acid or gel batteries for starting or for deep cycle operations. Such vehicles normally have space specifically designated for receiving and/or mounting such batteries and many provide for receiving or mounting a plurality of batteries. With the advent of efficient, low cost energy conversion devices such as inverters and chargers many vehicle owners desire to add these devices to their vehicles. However, space is limited on vehicles and often, there is no suitable place to mount or position such devices, thus limiting the owner's ability to make use of them.

What would be desirable is energy conversion device that is easy and convenient to mount in harsh environment areas on a vehicle.

SUMMARY OF THE INVENTION

The present invention addresses the above needs by providing an electrical energy conversion apparatus having a heat conductive base, a heat insulating cover operable to mate with the base so as to form a sealed space bounded by the cover and the base to prevent ingress of moisture, and a mount inside the space, for securing an energy conversion circuit to at least one of the cover and the base.

The energy conversion circuit may include an inverter and/or a battery charger.

The apparatus may further include a drain for draining liquid from inside the space and may have a battery form factor such as a generally rectangular parallelepiped shape enabling the apparatus to occupy a space occupiable by a battery and may further include provisions for securing the apparatus in the space occupiable by a battery.

The apparatus may also include a vent in at least one of the base and the cover for venting humid air from the space. The vent may be located in the base and may include a moisture permeable membrane allowing moisture to pass from the space to an area outside the apparatus.

The apparatus may also include a drain comprising an opening in the base and a resilient seal covering the opening. The resilient seal may be movable in response to a pressure difference between the sealed space and ambient pressure to allow fluid to pass through the opening.

The base and/or the cover may have sealable openings through which electrical conductors of the energy conversion circuit may pass. The cover may be formed from plastic and the base may be formed from metal and may have provisions for mounting the apparatus to a battery mount. The base may further have a transformer mount, for mounting a transformer of the energy conversion circuit.

The apparatus may include an energy conversion circuit mounted in an airspace inside the sealed space and may include a plurality of switching devices configured to reduce heat generation sufficient to permit the energy conversion circuit to operate while the apparatus is in an area having an ambient temperature range between about −40 degrees centigrade to about +85 degrees centigrade. The plurality of switching devices may include a plurality of transistors connected in parallel.

The energy conversion circuit may further include a transformer configured to reduce heat generation sufficient to permit the energy conversion circuit to operate while the apparatus is the above mentioned temperature range. The energy conversion circuit may also include a plurality of circuit boards and a vibration damper for dampening vibrations of the circuit boards. The vibration damper may include supports extending between the circuit boards. One support may include a guide and at least one of the circuit boards may have an opening for co-operating with the guide to guide the at least one circuit board in sliding movement relative to the other.

The mount for mounting the energy conversion circuit may include holders in the base and/or in the cover for holding circuit boards of the energy conversion device in spaced apart relation while permitting the at least one circuit board to move relative to the other, to facilitate sealing between components on the circuit boards and the cover while permitting access to the components, from outside the cover.

Other aspects and features of the present invention will become apparent to those ordinarily skilled in the art upon review of the following description of specific embodiments of the invention in conjunction with the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

In drawings which illustrate embodiments of the invention,

Figure 1 is an isometric view of an energy conversion apparatus according to a first embodiment of the invention;

Figure 2 is an isometric view of a base shown in Figure 1;

Figure 3 is an isometric view of a cover shown in Figure 1;

Figure **4** is an isometric view of the base shown in Figure **1** with an energy conversion circuit installed therein;

Figure **5** is an isometric view of a vent of the apparatus shown in Figure **1**;

Figure **6** is a schematic diagram of a battery charger according to one embodiment of the invention;

Figure **7** is a schematic diagram of an inverter according to an alternate embodiment of the invention; and

Figure **8** is a schematic diagram of an inverter/charger according to an alternate embodiment of the invention.

DETAILED DESCRIPTION

Referring to Figure **1**, an electrical energy conversion apparatus according to a first embodiment of the invention is shown generally at **10**. The apparatus **10** comprises a heat conductive base **12**, a heat insulating cover **14** operable to mate with the base so as to form a sealed space bounded by the cover and the base **12**, to prevent ingress of moisture, and referring to Figures **2** and **3**, the apparatus further includes a mount, which in this embodiment includes holders shown generally at **16** in the base **12** as shown in Figure **2** and holders shown generally at **18** in the cover **14** as shown in Figure **3**. The holders **16** and **18** are operable to secure an energy conversion circuit shown generally at **20** in Figure **4** to at least one of the cover **14** and the base **12**. In particular, the holders **16** and **18** may hold a plurality of circuit boards of the energy conversion circuit **20**, in spaced apart relation. In this embodiment, the energy conversion circuit **20** shown in Figure **4** includes a combination battery charger and an inverter as shown in Figure **6**, but could alternatively just comprise an inverter as shown in Figure **7** or just a charger as shown in Figure **8**, or could include any other type of electrical energy conversion

device. In this embodiment, the energy conversion circuit comprises a transformer **30** and a plurality of circuit boards **110**, **112** and **114**.

Referring to Figure **2**, the base **12**, in this embodiment, is formed of a heat conductive metal, such as aluminum, for example. The base **12** may be cast and machined to include the mounts **16**, for example. In this embodiment, the base **12** further includes a transformer mount **22** including a cavity **24** bounded by a wall **26** having mounting openings **28** therein for securing the transformer **30** of the energy conversion circuit thereto.

Referring to Figure **4**, the transformer **30** is mounted to the wall portion **26** such that an opposite portion of a winding **32** of the transformer is received in the cavity **24** shown in Figure **2**. The wall **26** shown in Figure **2** is solid metal and when the transformer **30** shown in Figure **4** is mounted to the wall using screws **34**, for example, heat dissipated by the windings **32** and transformer core **36** is transferred to the base **12** with low thermal resistance. In this embodiment, the transformer **30** is designed for high temperature operation and is configured to reduce heat generation sufficient to permit the energy conversion circuit to operate while the apparatus is in an ambient temperature range of between about **-40** degrees centigrade to about **+85** degrees centigrade. This is a typical operating temperature range of an engine compartment of a conventional passenger vehicle. To achieve this temperature range, the transformer has heavy gauge windings to reduce electrical resistance and a heavy core to reduce eddy current losses.

In addition, the energy conversion circuit **20** includes a plurality of switching devices **113** mounted on the circuit boards, in this embodiment the third circuit board **114**. The switching devices are configured to reduce heat generation sufficient to permit the energy conversion circuit **20** to operate within the above indicated temperature range. In particular, this is achieved by connecting at least some of the plurality of switching devices **113** in parallel. Referring to Figure **6**, in this embodiment, the energy conversion circuit **20**

includes a combination inverter/charger which has four "switching" legs **115, 117, 119, 121**. Each switching leg is comprised of twelve metallic oxide semiconductor field effect transistors (MOSFETs) connected in parallel to provide a very low "on" resistance in each leg, which reduces heat dissipation. The use of the above described transformer mounting method, the transformer **30** and the arrangement of switching devices **113** reduces the amount of heat generated by the energy conversion circuit **20**, enabling it to maintain operation in the sealed environment provided by the base **12** and cover **14**, when the apparatus **10** is operated in the above described ambient temperature range.

Referring back to Figures **1** and **2**, the base **12** also has a plurality of receptacles, one of which is shown at **40**, for receiving fasteners from an underside of the base, to engage with the cover **14**. The base **12** also has a perimeter groove **42** for receiving a complementary shaped rubber seal, only a portion of which is shown at **43** therein, and referring to Figure **3**, the cover has a shoulder portion **44** which presses the seal into the groove **42** such that the seal **43** acts as a sealing gland in the groove, to prevent the ingress of moisture and/of dirt and/or chemical contaminants into the space bounded by the base **12** and the cover **14**.

Referring to Figure **1**, the cover **14** is formed from an ABS/polycarbonate plastic which makes it resistant to chemicals such as battery acid. The cover **14** is shaped to have a lip **46** which extends partially over the top perimeter of the base **12**, such that any water or liquid running down the cover is deflected away from a joint formed between the base and the cover.

Referring to Figure **3**, the inside of the cover has a plurality of bosses, one of which is shown at **50**, for receiving fasteners inserted through openings such as **40** in the base **12**, to secure the cover **14** to the base. In this embodiment screws may be used to hold the cover to the base. The openings **40** may be sealed by O rings **51** or sealing compound, for example.

Referring to Figures **2** and **3**, in this embodiment, the holders **16** and **18** are in the form of L-shaped slots, one of which is shown at **120** in Figure **2**. Referring to Figures **2** and **4**, the circuit boards **110**, **112** and **114** are slidingly received in these slots **120** such that the circuit boards may slide and be held therein, in the orientation shown in Figure **4**. It will be appreciated that, referring to Figure **4**, when the cover **14** is placed over the base **12** as shown in Figure **1**, slots such as **122** shown in Figure **3** receive edges of the circuit boards **110**, **112** and **114** respectively.

In this embodiment, the energy conversion circuit includes two circuit boards **110** and **114** which have components which must be accessible from outside of the cover, as shown in Figure **1**. Due to tolerance stacking as a result of the mechanical tolerances which add up over the length of the circuit boards, it is desirable to mount the two circuit boards **110** and **114** so that they remain substantially parallel, but at least one of the circuit boards can be vertically displaced relative to the other circuit board. Providing vertical displacement between the circuit boards facilitates sealing between the cover **14** and the externally accessible components on the first circuit board **110** and simultaneously facilitates sealing between the cover and the externally accessible components on the third circuit board **114**.

A vibration damper extends between respective circuit boards, and in this embodiment the damper includes supports **116** and **118** extending between the circuit boards. In this embodiment, the supports are provided by threaded standoffs.

To facilitate relative movement of the circuit boards **110** and **114**, in this embodiment the support for the first circuit board **110** includes a guide, which in this embodiment is provided by a screw **128** receivable in an opening which in this embodiment is an elongated slot **130** in the first circuit board **110** which

co-operates with the guide to guide the circuit board **110** in sliding movement relative to the second and third circuit boards **112** and **114**.

The cover **14** has a top portion **51** having openings **52** and **54** having hexagonal walls **56** and **58** respectively formed therearound, for receiving respective hexagonal nut members **60** and **62** of first and second conductors shown generally at **64** and **66**, on the third circuit board **114**, which are to be accessible from outside the cover. Rubber washers as shown at **68** and **70** are received in the areas bounded by the hexagonal walls **56** and **58** respectively, such that when the conductors **64** and **66** are received through the openings **52** and **54**, the rubber washers **68** and **70** are compressed between the nut members **60** and **62** and the top portion **51**, thereby sealing the area around the conductors, relative to the cover **14**, to prevent ingress of moisture into the space bounded by the cover and base **12**. The conductors may be configured to pass through either the cover **14** or the base **12**, provided the openings are sealed. The sealing method shown in Figures **3** and **4** is simply an exemplary sealing method.

The first circuit board **110** has externally accessible components including switches **74** and **76** for controlling the operation of the energy conversion circuit and connectors **78** and **80** for connecting to a remote control panel and for connection to an AC bus respectively. To suit these components, referring to Figure **3**, the cover **14** has a mating connector portion **82** disposed in a plane spaced apart from the top portion **51** and having openings, only three of which are shown at **84**, **86** and **88**, for receiving the switches **74** and **76** and connectors **78** and **80** therethrough. The switches and connectors may be fitted with rubber gaskets, which mate with the surface **90** of the connector portion **82** so as to form a seal around the connectors and switches to prevent the ingress of moisture into the space bounded by the cover **14** and the base **12**. Since the first circuit board **110** is movable relative to the third circuit board **114** positioning of the connector portion **82** relative to the components for sealing while maintaining a seal on the externally accessible components

on the third circuit board **114** is not seriously affected by tolerance stacking on the circuit boards and a good seal around all externally accessible components can be achieved.

Referring to Figures **3** and **4**, it will be appreciated that the sealed space bounded by the cover **14** and base **12** is an air space and, as such, there is a possibility that the air inside the sealed space may become humid. However, the heat insulating cover **14** and heat conducting base **12** cooperate to reduce condensation on the inside surfaces of the cover and keep any condensation on or near the base **12**. To facilitate removal of humid air from the air space, at least one of the base **12** and the cover **14** is provided with a vent and in this embodiment, referring to Figure **4**, the vent is shown at **100** on the base **12**.

Referring to Figure **5**, in this embodiment the vent **100** is a UNIVENT® manufactured by W.L. Gore & Associates, Automotive Products Group. The vent **100** includes a moisture permeable Gore-Tex® membrane **102** allowing moisture to pass in the direction of arrow **104** from the space bounded by the cover **14** and the base **12** to an area outside the apparatus **10**. Referring to Figure **2**, the base **12** may be formed with a boss **105** having an opening **106** for receiving and holding the UNIVENT as shown in Figure **4**.

Referring to Figure **2**, to further facilitate removal of moisture from the sealed space, the base **12** may be fitted with a drain having an opening **108**, which is preferably positioned at a lowest point in the base. Thus any liquid which condenses on the base, runs to the drain and any air pressure buildup within the space, due to heating of the components of the energy conversion circuit **20**, causes a resilient seal **109** covering the opening to open slightly in response to a pressure difference between the sealed space and ambient pressure, to permit the liquid to be expelled.

Referring to Figure **1**, when the cover **14** is mounted to the base **12**, the cover and base have a generally rectangular parallelepiped shape, although walls

91, **92**, **94** and **96** of the cover are slightly inwardly tapered toward a top portion of the cover **14**. The cover **14** and base **12** are formed so as to generally have a conventional lead acid battery form factor which enables the apparatus to occupy a space which would normally be occupiable by a lead acid battery. Thus, the apparatus **10** effectively provides a housing for the energy conversion circuit **20** and the housing has a form factor enabling the apparatus to be installed in a position normally occupied by a conventional lead acid battery. The conductors **64** and **66** protrude from the cover **14** in a manner similar to that in which battery posts protrude from a battery, thus facilitating easy connection of the conductors **64** and **66** to adjacent batteries, with short leads. The sealing engagement between the cover **14** and the base **12** and the sealing around the conductors **64** and **66** and switches **74** and **76** and connectors **78** and **80** render the apparatus **10** spray resistant enabling it to withstand pressure washing and rugged physical conditions including ambient heat and humidity extremes and vibration. Consequently, the apparatus **10** is quite suitable for mounting on a vehicle subjected to these extremes.

While specific embodiments of the invention have been described and illustrated, such embodiments should be considered illustrative of the invention only and not as limiting the invention as construed in accordance with the accompanying claims.